RT Modelling of CMEs Using WSA-ENLIL Cone Model

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(original presentation by A. Taktakishvili)

Space Weather Training at KSC

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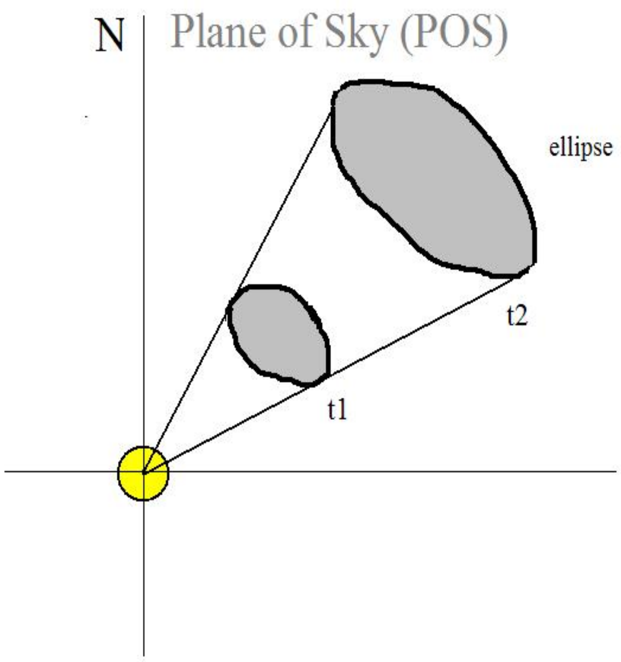
Outline

- Basic Principles behind cone modeling of CMEs.
- Brief description of the models
- Analyzing CME propagation and impact
- Operations

Cone Model for CMEs



The projection of the cone on the POS is an ellipse

Zhao et al, 2002, Cone Model:

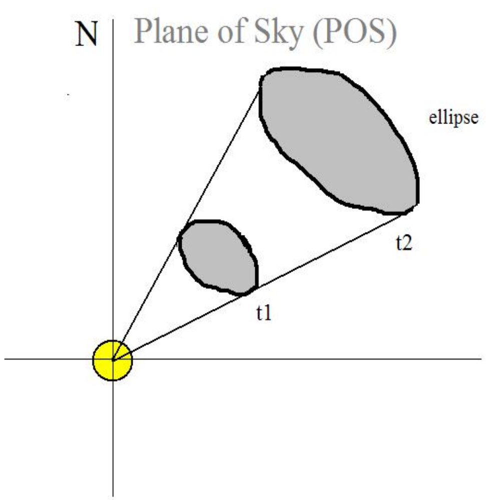
The CME cone model is based on observational evidence that CME has more or less constant angular diameter in corona, being confined by the external magnetic field, so that CME does not expand in latitude in the lower corona, but expands in interplanetary space because of the weaker external field

- CME propagates with nearly constant angular width in a radial direction
- CME bulk velocity is radial and the expansion is isotropic

Overly simplistic approximation to describe halo CME

Cone Modelling for Halo CMEs

SOHO LASCO C3 difference images



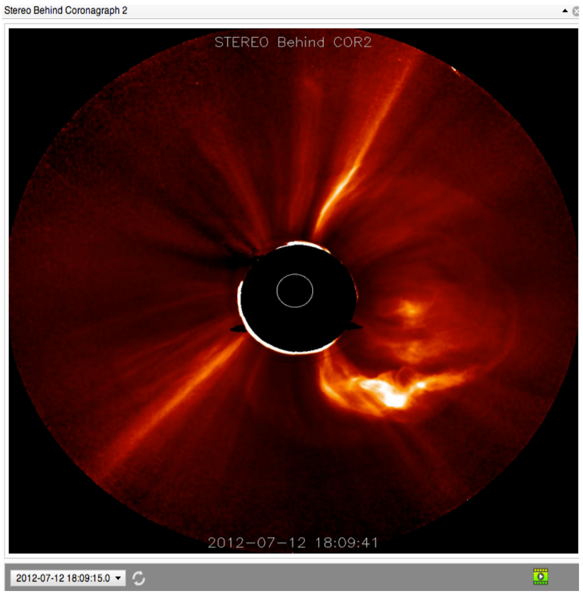
Xie et al, 2004, Cone Model for Halo CMEs – analytical method

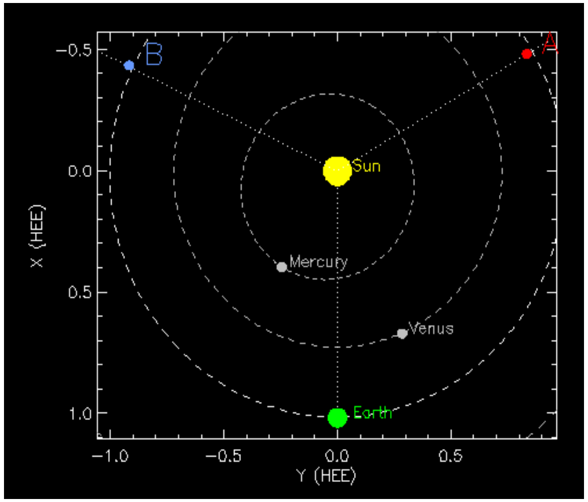
A. Pulkkinen, 2010, Cone Model for Halo CMEs – automatic method

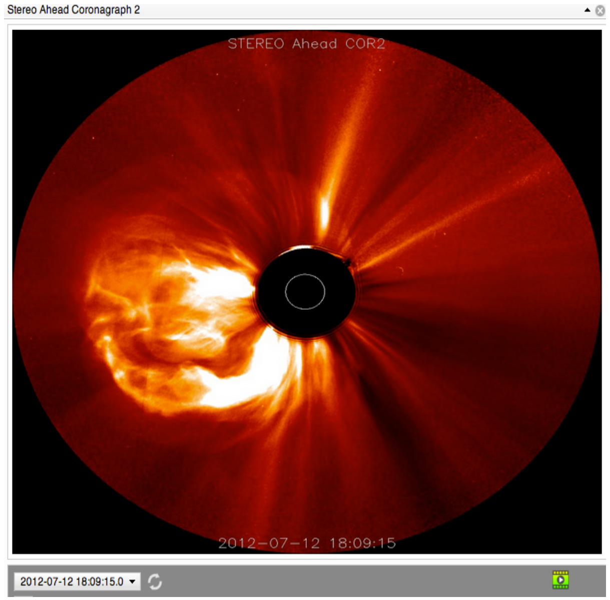
CME V and orientation

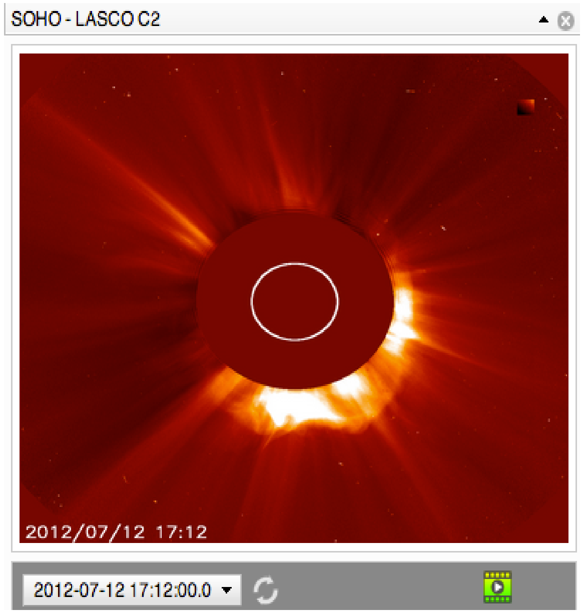
Input to WSA-ENLIL

July 12, 2012CME Viewed by Coronagraph Imagers



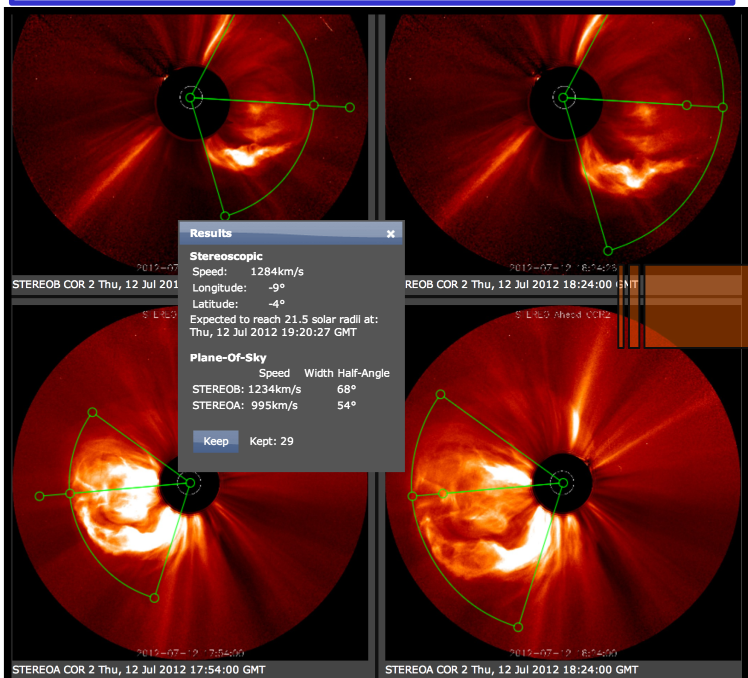




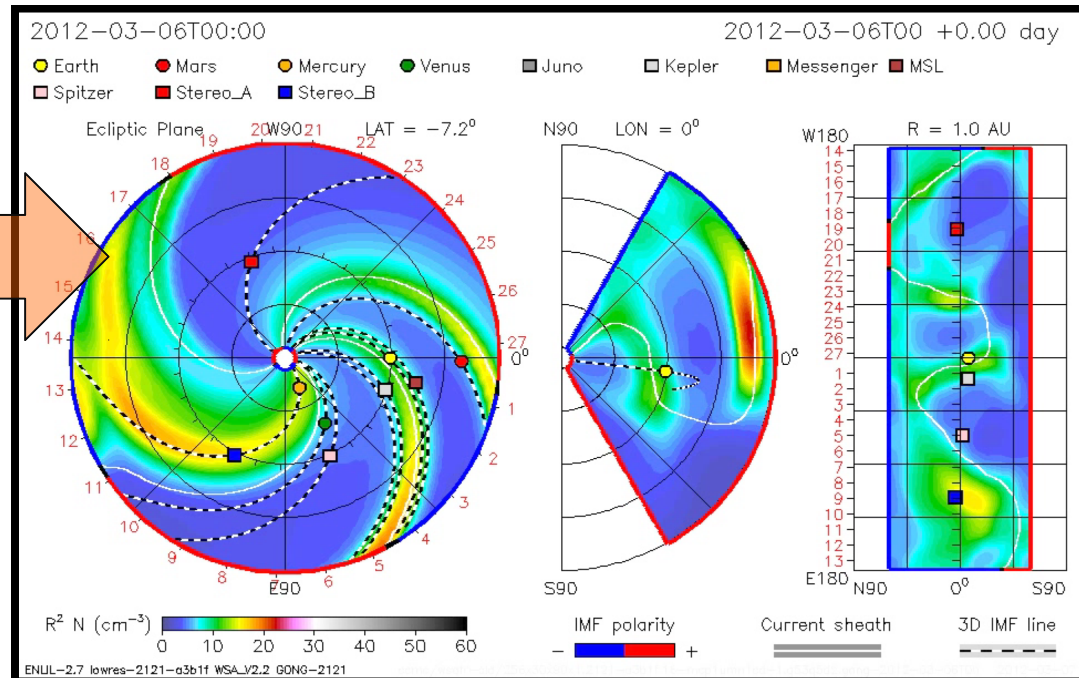


WSA-ENLIL Cone Model

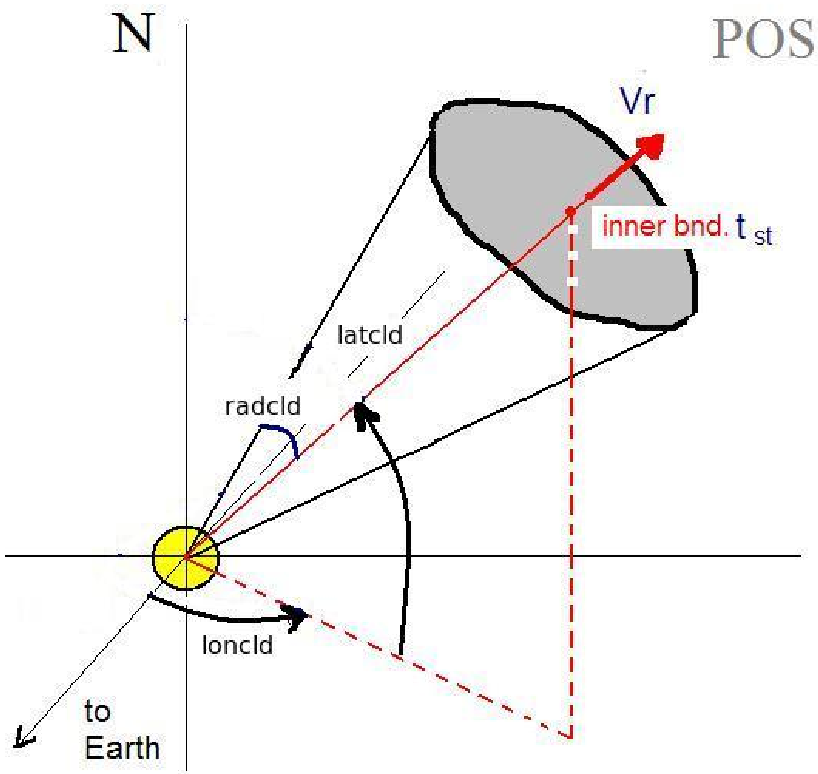
Parameters Defined with CCMC CME Triangulation Tool



CME Parameters: Input To WSA-ENLIL Cone Model



Cone model parameters

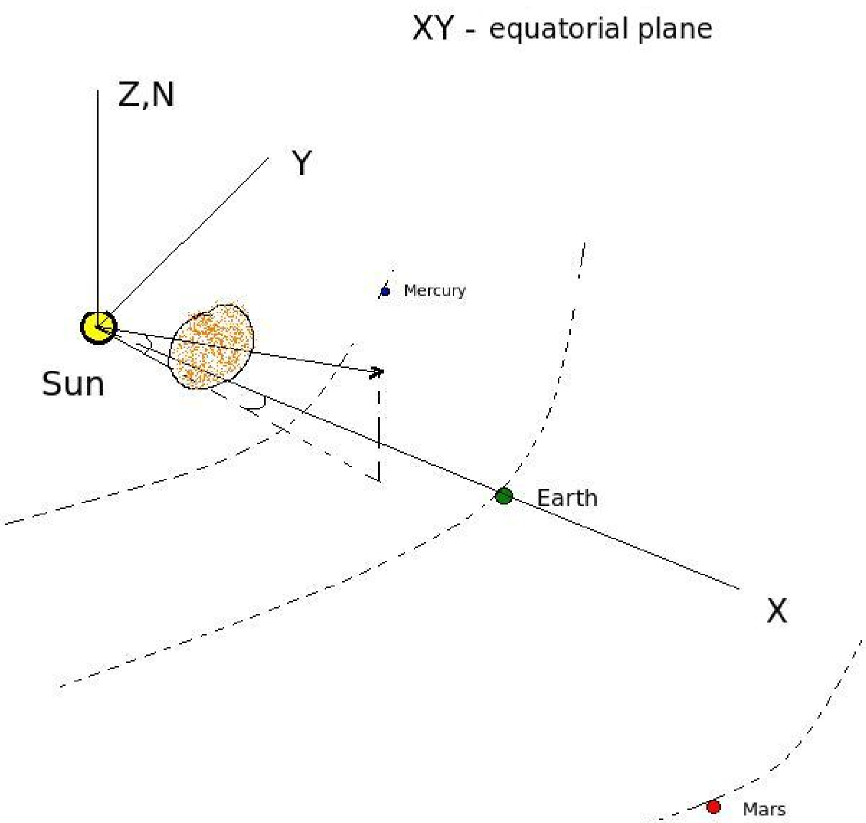


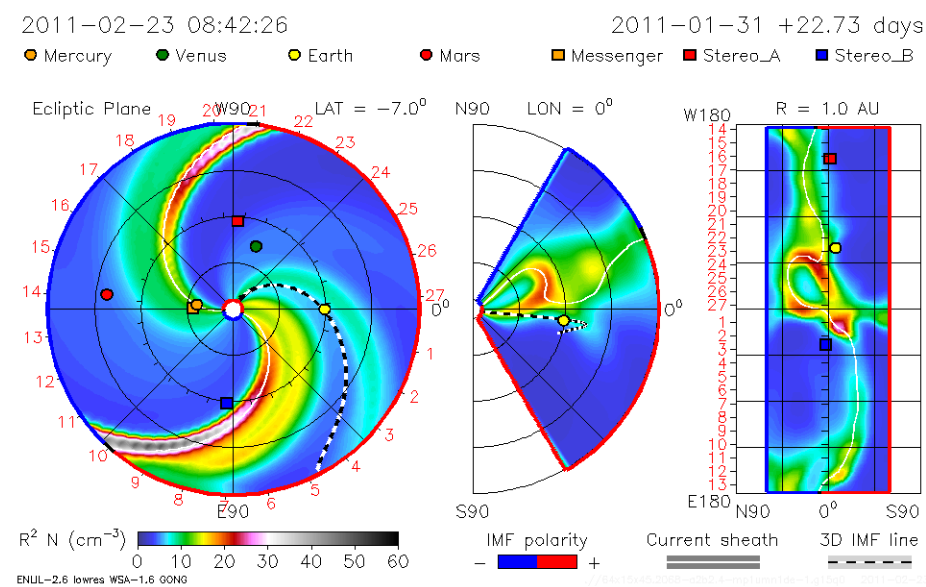
- tstart - when cloud at 21.5Rs
- Latitude
- Longitude
- Radius (angular width)
- Vr - radial velocity

Input to ENLIL cone model run

Sun, Planets, CME

Heliocentric Earth Equatorial Coordinates - Heliographic





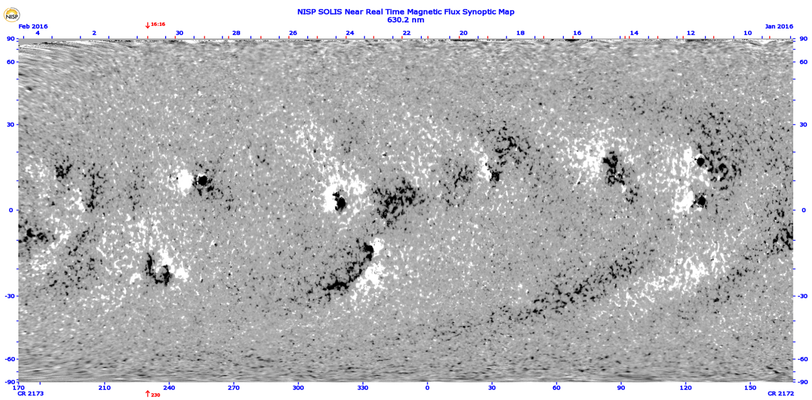
Constant Latitude Plane passing through Earth (polar view)

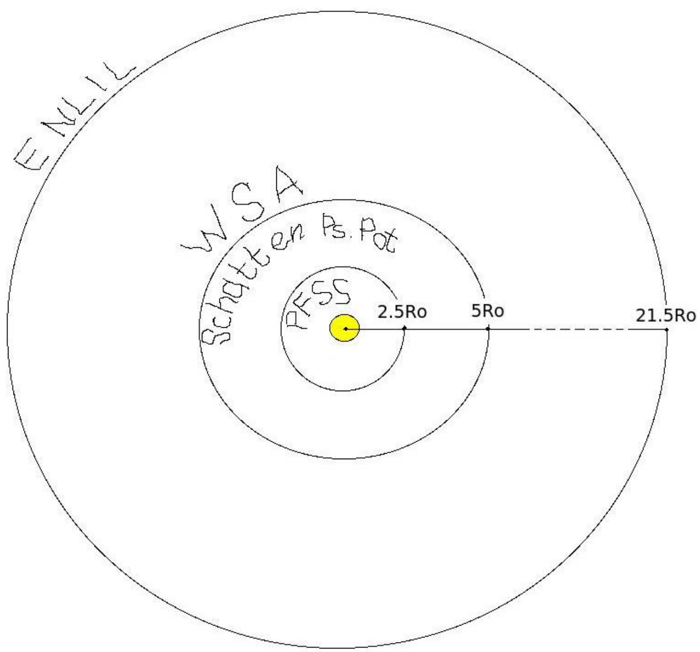
Meridional Plane ('side' view)

1AU quasi-sphere

WSA- Input to ENLIL

WSA (Wang-Sheeley-Arge, AFRL):



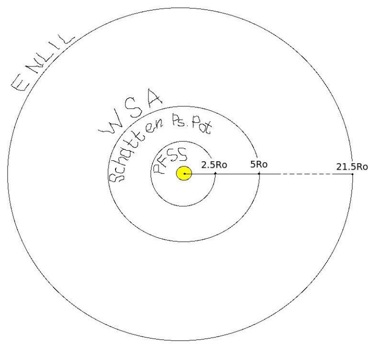


- **PFSS** (Potential Field Source Surface)**.**
  Input: synoptic map photospheric magnetogram.
  Force free (even current free) solution with radial field at 2.5 Ro.
- **Schatten Current Sheet**.
  Input: PFSS.
  Modifies the sign of radial field to positive to prevent reconnection, creates potential solution with radial boundary conditions, restores the sign in the new solution at 5 Ro.
- **WSA.**
  Input: Schatten CS.
  Assuming radial constant speed flow at 5 Ro uses empirical formula for speed, determined by the rate of divergence of the magnetic field at 5 Ro and proximity of the given field line to the coronal hole boundary.

ENLIL - Schematic Description

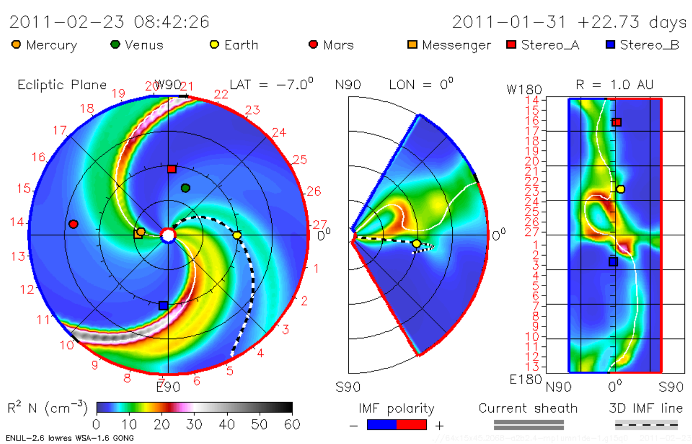
ENLIL – *Sumerian God of Winds and Storms*

Dusan Odstrcil, GMU & GSFC



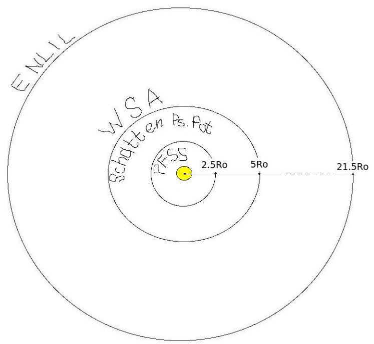
Input: WSA (coronal maps of Br and Vr updated 4 times a day). For toroidal components at the inner boundary- Parker spiral.

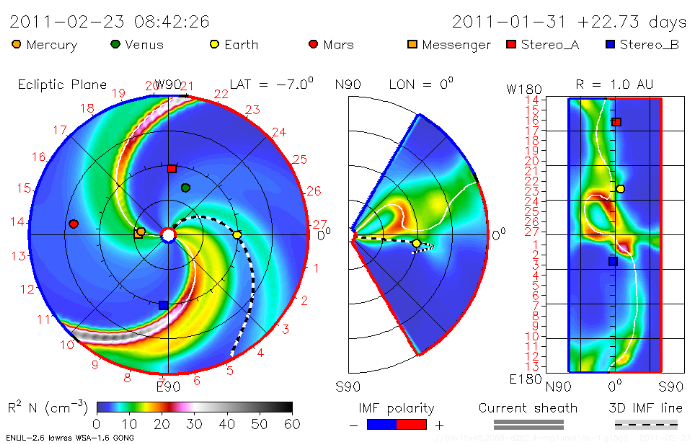
ENLIL's inner radial boundary is located beyond the sonic point: the solar wind flow is supersonic in ENLIL.



Computes a time evolution of the global solar wind for the inner heliosphere, driven by co-rotating background structure and transient disturbances (CMEs) at it's inner radial boundary at 21.5 Ro. Solves ideal fully ionized plasma MHD equations in 3D with two additional continuity equations: for density of transient and polarity of the radial component of B.

ENLIL Schematic Description (cont.)



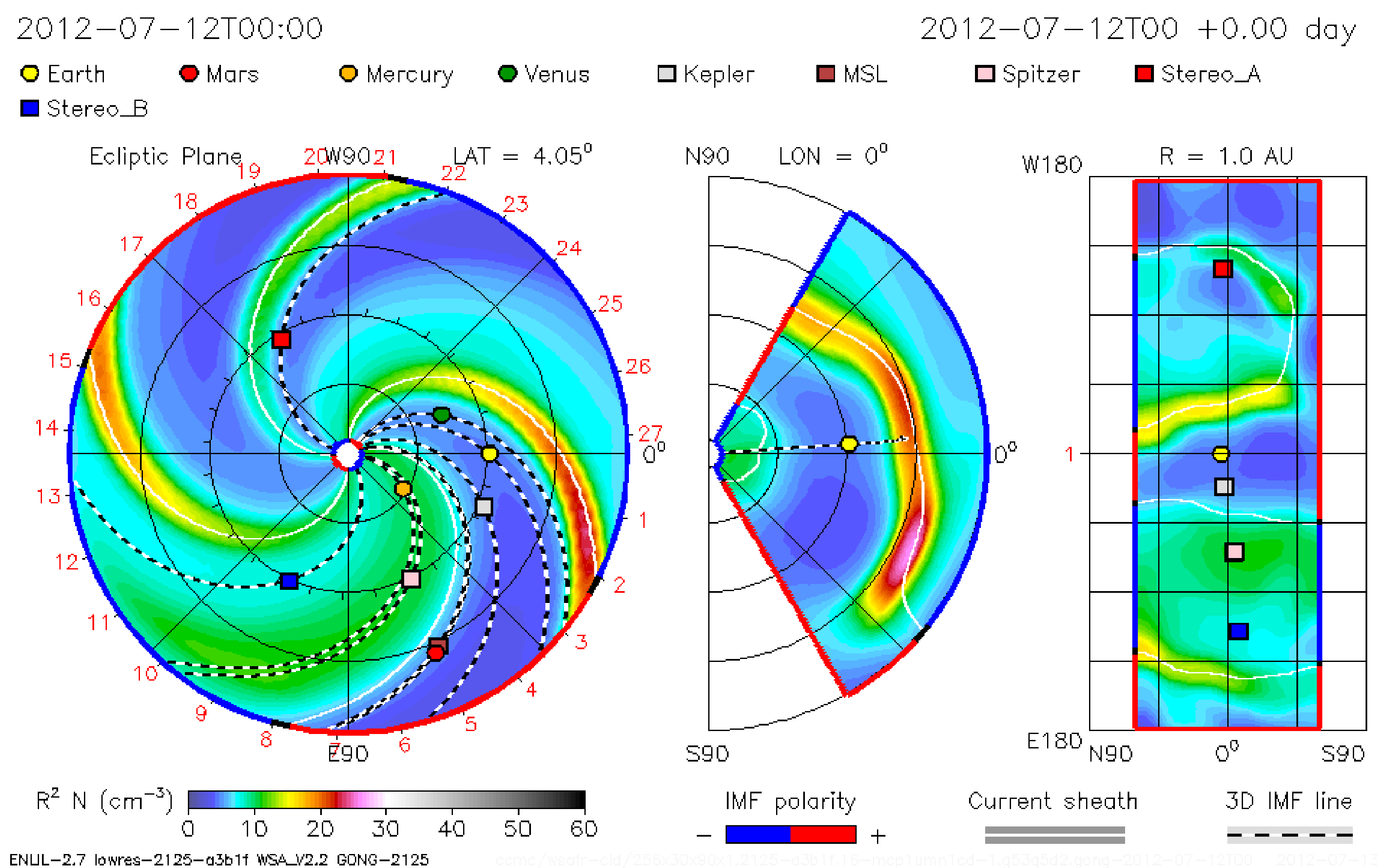


ENLIL model does not take into account the realistic complex magnetic field structure of the CME magnetic cloud and the CME as a plasma cloud has a uniform velocity.

It is assumed that the CME density is 4 times larger than the ambient fast solar wind density, the temperature is the same. Thus, the CME has about four times larger pressure than the ambient fast wind. Launching of an over pressured plasma cloud at 21.5 **Rs,** roughly represents CME eruption scenario

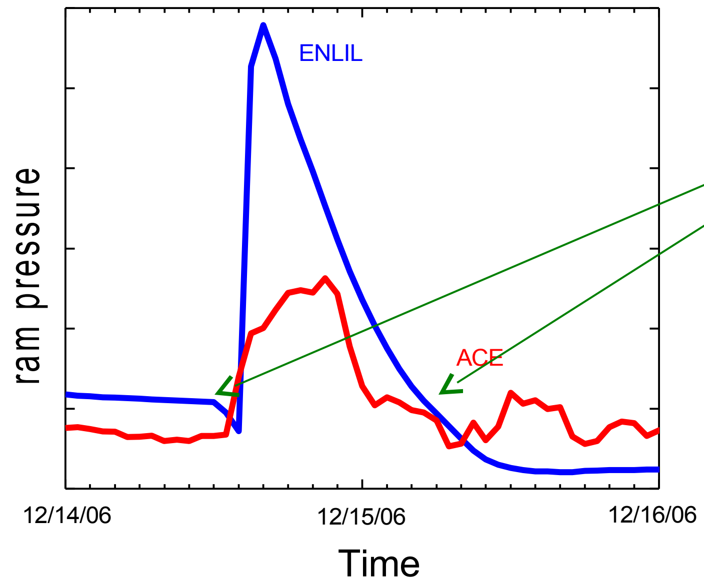
Output:
3D distribution of the solar wind parameters at spacecrafts and planets and topology of the interplanetary magnetic field.

CME modeling



CME Impact – arrival, duration, MP standoff distance, Kp index

CME shock arrival – a sharp jump in the dynamic pressure



Duration of the disturbance – duration of the dynamic pressure hump

Empirical equations for:

- Magnetopause standoff distance

- Kp Index (measure for the strength of the geomagnetic storm)

e-mail with CME impact estimate at Earth

Arrival time(year/month/day, hr:min UT) =2012-07-31T15:02Z
(confidence level +-7 hours)

Duration of the disturbance (hr) = 10.3
(confidence level +-8 hours)

Minimum magnetopause standoff distance: Rmin(Re)=5.6
(under quiet conditions: Rmin(Re)=10;
R_geosynchr(Re)=6.6)

Kp index for three possible IMF clock angles
(angle 180 gives the maximum possible estimated Kp):
(Kp)_90=4
(Kp)_135=6
(Kp)_180=7

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Here are the links to the movies of the modeled event

http://iswa.gsfc.nasa.gov/downloads/20120729_014700_afwa_anim.tim-den.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_afwa_anim.tim-vel.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_afwa_anim.tim-pdyn.gif

Inner Planets
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-den.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-vel.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-den-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-vel-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-den-Stereo_B.gif
http://iswa.gsfc.nasa.gov/downloads/20120729_014700_anim.tim-vel-Stereo_B.gif

Timelines
http://iswa2.ccmc.gsfc.nasa.gov/downloads/20120729_014700_ENLIL_CONE_timeline.gif
http://iswa2.ccmc.gsfc.nasa.gov/downloads/20120729_014700_ENLIL_CONE_Kp_timeline.gif

e-mail for NASA missions

Mars
****

CME did not hit the Mars.
or
CME impact is very weak.

****

Stereo A
****

CME did not hit the StereoA.
or
CME impact is very weak.

****

Stereo B
****
CME did not hit the StereoB.
or
CME impact is very weak.

****

Spitzer
****

Arrival time(year/month/day, hr:min UT) =2015-05-11T20:49Z

Inner Planets
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-den.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-vel.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-den-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-vel-Stereo_A.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-den-Stereo_B.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_anim.tim-vel-Stereo_B.gif

Inner Planet Timelines
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_Mars_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_STA_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_STB_timeline.gif
http://iswa.gsfc.nasa.gov/downloads/20150509_071500_2.0_ENLIL_CONE_Spitz_timeline.gif
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